manifestly survives over one or more winters, while the other species, to judge from their weak attachments, may be annual.

Vern. *Tuzg.*—Sent by Col. C. A. MacMahon from the Helmund lagoons where it is gregarious and abundant, with *Arundo Donax* Linn., *Scirpus maritimus* Linn., and other fen plants of the temperate and sub-tropical zones of the northern hemisphere.

Named after the writer's friend, Mr. T. J. R. Ward of the Punjab Irrigation Department, who has supplied full and interesting notes on this collection of aquatic species from the Helmund.

The Himalayan summer storm of September 24th, 1903, and the weather immediately subsequent to that date in Northern India.[1]—*By* C. Little, M.A. (With Plate VI.)

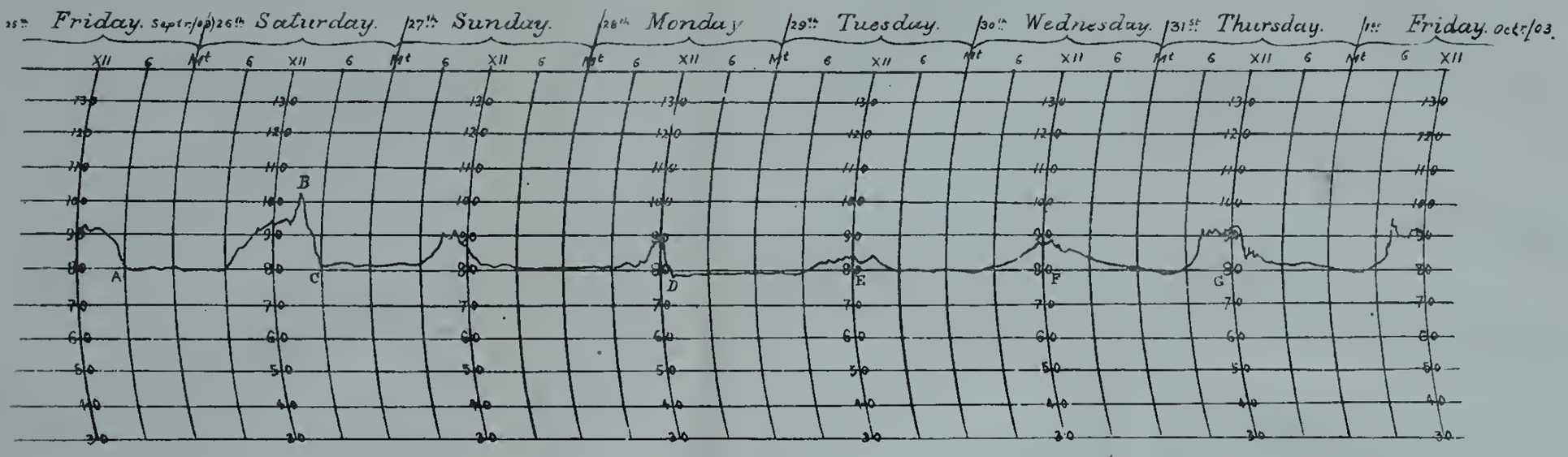
[Read March 2nd, 1904.]

Although in this paper some reference is made to the past two rainy seasons, the discussion in the main deals with occurrences towards the close of the monsoon season of 1903. My reason for making this arrangement is the belief that these later events bring into stronger relief the importance of considering to what these events are due. It will, I am sure, be obvious to all that until such occurrences can be fully accounted for afterwards, there is no prospect of their being foreseen with even a semblance of accuracy.

In the *Englishman* of September 15th, 1903, there appeared the usual weekly report of Meteorological observations at St. Xavier's College. To that report a note was added giving expression to the idea that the monsoon season had practically come to an end in Northern India. The note closed with the following sentence: "This year, 1903, there seems therefore to be greater fear for a speedy termination of the rainy period."

1 In the Monthly Weather Review for September 1903, published in February 1904, the following is the summary of the weather in the former month:—

"During September 1903, the weather was more disturbed than usual over the Bay area and surrounding regions, occasioned by a series of small storms which was developed over the Bay, and thence progressed through the central parts of the country into Upper India. Over Western India, on the contrary, the weather was fairly quiet. The south-west monsoon was, on the whole, weaker than usual over the Arabian Sea, and the rains ceased at about the normal date over North-west India."



A *marks the fall of temperature with the thunder-storm between 5 & 6 P.M. on the 25th.*

B. " *the high temperature due to direct sunshine.*

C " *the fall of temperature with the thunderstorm between 5 & 6 P.M. on the 26th*

D " *the fall of temperature about noon of the 28th.*

E " *the small range of temperature during the cloudy rainy weather while the depression was over lower Bengal.*

F & G " *the steady recovery of temperature after the depression moved westward*

In the *Pioneer* of September 28th, the following remark appeared: "The sky is becoming clear all over Upper India, and fine weather is now promised by the Meteorological Department."

Ten days later the *Pioneer* wrote as follows: "On the 26th or 27th September the Meteorological Bureau seems to have arrived at the conclusion that fine weather conditions were becoming established over Upper India just on the eve of one of the most heavy and prolonged bursts of rainfall that can ever have been recorded so late in the year. Even now the daily telegrams seem to show no appreciation of the extraordinary character of the season in which October seems to have changed places with July. Down to the end of the former month there was every reason to apprehend in these Provinces that the autumn crops would be a failure from the want of rain. The danger now is that they may be ruined by too much of it. Already serious damage must have been done in places, and the telegrams to-day give a lively picture of the state of things in the Deccan and especially at the capital. Railway communication has been severed between Madras and Secunderabad. There are even fears that the great Hussain Saugor Tank may burst its bounds, and already thousands of people belonging to the villages along its banks are said to have been rendered homeless."

My object in quoting the above remarks from the daily press I will give presently. But before going on to the subject of the paper I may perhaps be permitted to point out, that it is not apparent, whether the criticism of the writer in the *Pioneer* is directed against the system on which weather forecasting is done in this part of the world, or whether it is against the subordinates, I might almost say the rank and file of the Weather Bureau who, in no way responsible for the system, still have a responsibility as regards the application of that system to daily occurrences. I have not been able to verify the accuracy of the statement in the *Pioneer* that the Weather Bureau had come to the conclusion that fine weather conditions were becoming established, but there is not much doubt that such was the case, because on the present system of weather forecasting there was no other alternative. The chief feature of the present system, at times other than when weather is controlled by a well-marked cyclonic storm, is in the estimate of the strength of what is called the Arabian Sea monsoon current and the Bay of Bengal monsoon current. If these currents are both weak, then diminished rainfall is considered inevitable in Northern India; and when this weakening of the monsoon current on both sides of the peninsula is accompanied by the commencement of the change of season in Upper India, about the usual time, the chances of more rainfall in that region are greatly diminished. Now, in September of the past year, there was

practically no monsoon either in the Arabian Sea or in the Bay of Bengal, if it be understood that a smooth sea and comparatively light winds indicate the absence of monsoon; and, as the *Pioneer* states, the skies had become cloudless in Upper India. We have also the evidence of the meteorologists of St. Xavier's College, Calcutta, that in their opinion the rains would terminate early—an opinion given quite independently of the Weather Bureau. Assuming that the chances were 10 to 1 against a disturbance developing in the Bay of Bengal or the Arabian Sea during the latter half of September or first week of October, and 10 to 1 against that storm moving north-westward, if it happened to form, the chances were 100 to 1 against rainfall in the United Provinces or the Punjaub. The above chances are not at all unlikely if we remember that the monsoon had become exceedingly weak in the Indian sea area, and that the sky had become cloudless in Upper India: or, in other words, that atmospheric conditions in the north of India and the Bay of Bengal were such as in ordinary years are experienced in the early part of October. Experience has shown that under such circumstances no cyclonic storm has ever advanced from the Bay of Bengal or the Arabian Sea in the direction of North-west India.

The conclusion therefore is that the subordinates of the Weather Bureau had two alternatives. They had either to stand by the system and come to the conclusion that rainfall had ceased for the year in North-West India, or they had to put aside the system and strike out a new course for themselves. That the former course was adopted is in my opinion not only natural; the adoption of any other was impossible.

One of my reasons for making the above newspaper quotations is to emphasise, as strongly as it is possible to do, the fact that weather in Northern India just after the middle of September was of a kind to suggest an early termination of the rains in Northern India, and that before the end of the first week of October rainy weather of an intense character had become established over a great part of Northern India.

A change so noticeable, as that most undoubtedly was, must have been due to well-marked local causes, which ought to become apparent on subsequent enquiry. Now whether these causes can be brought to the surface from the meteorological records or not, there can be no question that the events of the early days of October were not foreseen, and in my opinion could not, under the present system, have been foreseen, for reasons which I have been trying to make clear in previous papers read before this Society. Until the atmospheric processes are better understood than they are at present, it is a mere truism to state that even approximately accurate forecasting is impossible.

The criticism of the *Pioneer* if just, makes it obligatory on some one to revise present-day methods of meteorologists in India, and cannot be entirely overlooked by even the most humble worker or writer. I have given my opinion that any fault, there may have been, cannot be laid at the door of the subordinates who were carrying on the daily routine of weather reporting and forecasting. It must, therefore, have been the system that failed, and as that system is intimately connected with the subject of this and other papers which have been read by me before this Society, I will pause for a brief reference to that system. I may be permitted to point out that atmospheric problems, whether simple of their kind or complex, are of such unusual difficulty, that their treatment must of necessity, in any department such as a Weather Bureau, be the special responsibility of the head of the department; and that the success or failure of a system, whether in its bearing on past events, or as the basis of weather forecasting, is a matter, from the point of view of science, of strictly personal reckoning. On that ground I may be excused somewhat repeated reference in the few general remarks that follow to Mr. Blanford and Sir J. Eliot, who have controlled meteorological work in India during the past thirty to forty years.

It requires only a cursory examination of the meteorological history of the early years of the department to realize, even in the light of the accumulated experience of the intervening years, how sound was the instinct displayed, and practical the view that was taken of the possibilities of meteorological work in India by its founder, Mr. H. F. Blanford of immortal memory. Nothing affords a more striking illustration of his power of separating what may be called casual occurrences, or from those indicating important or controlling causes, than his method of estimating the strength of the coming monsoon, and theory has received more encouraging confirmation than his is receiving at the present time, twenty years after it was formulated. That theory has been given in published reports and in the Proceedings of the Royal Society, and its distinctive feature is the connection between the condition of the upper atmospheric strata as indicated by snowfall in the Himalayas, and the character of the coming monsoon. The following extracts are taken from his report on the Meteorology of India in 1882:—

> "In Europe and America, the attention of the leading Meteorological Physicists would seem to have been concentrated of late years mainly on the physics of the vortical movements of the atmosphere of cyclones and anticyclones, the importance of which is keenly felt, owing to the prominence given to storm

warnings and forecasts, of impending weather among the objects of the national systems of weather report."

"In India storm warnings also have an importance, but it is chiefly local and restricted to certain seasons of the year: and other and more comprehensive problems force themselves on our attention and await their solution at our hands. Foremost among these are all questions bearing on the vicissitudes of the rainfall."

After pointing out that seasons of drought are due to the persistence of certain winds, the report continues:—

"The experience of recent years indicates that a season in which the pressure of the higher atmospheric strata is excessive is one in which the land winds are unduly prevalent; and by a process of exhaustive reasoning, supported by occasional observation, I have been led to infer that, except at certain times in the cold season, the higher strata of the atmosphere lying over the mountain zone around North-Western and Western India, are the principal and immediate source of these winds."

"It would be out of place to enter here on an exposition of the reasons which have led me to this view; and it is my intention to give them in another place. Moreover, systematic observation of a kind which we can hardly expect from the class of men, who furnish the registers of our observatories, is yet required to confirm its accuracy. What is more especially required now, is a knowledge of the prevailing movements of the higher atmospheric strata, as indicated by those of the clouds characteristic of great elevations; and this requires watchfulness and judgment only to be expected of educated observers who take an intelligent interest in the conduct of the observations. Such persons are at present extremely rare in India."

Later at page 69 of the same report the following important opinion is recorded: "The main fact which is thus becoming more and more firmly established, as each successive year furnishes its additional mead of evidence, is that the character of the Indian weather is in a large measure determined by the barometric condition of the higher atmospheric strata."

In the annual report for 1883 (a year of crop failure) Mr. Blanford says:—

"It has been shown in former reports, more especially that for 1878, that years of severe and prolonged drought have been those in which the pressure of the atmosphere has been unduly high, and there is in all probability a direct connection between

this condition and the persistence of the dry winds in those years. But there is evidently some other condition which operates in producing these winds, and in retarding or interrupting the rainfall in years such as 1883, when the atmospheric pressure does not exceed the average and may even be below it. The dry winds in such seasons are less lasting, but for a time they are as strongly marked as in famine years. I have given elsewhere my reasons for believing that in such cases they are due to an unusual extent to the thickness of snow on the North-Western Himalayas.

* * * * * *

But there were indications that throughout this rainy interval the influence of the snows was operative. On the North-Western Himalayas, the rain of the first half of July was accompanied with frequent thunderstorms and hail storms (always a sign of an unsteady monsoon), and in clear intervals, the upper clouds could be seen drifting steadily from the North-West, proving the existence, at no great height, of the dry current which about the 19th descended and replaced the monsoon, prevailing over the whole of Northern India and Rajputana, and influencing the winds down to the Deccan on the south and Bihar on the east."

Further reference is made in the report for 1884, to the connection between the North-Westerly winds, the snowfall in the Himalayas and the rainfall distribution in Northern India; and in the report for 1885, the last which Mr. Blanford wrote before retirement, the following remark occurs:—

"The year under review affords a very striking instance, in confirmation of the hypothesis, on which these latter forecasts have been principally based, *viz.*, that the persistence of dry North-Westerly winds in Western India and Westerly winds in Northern India is greatly influenced by the depth and extent of the snow accumulation on the North-West Himalayas."

It will, I think, be clear from the above extracts that an important factor, in Mr. Blanford's opinion, in estimating the character of the Weather in Northern India, not only for the monsoon season as a whole, but for brief periods ahead, was connected with the upper atmospheric strata.

He repeatedly expresses his conviction of the need of some influence from the North, "some condition which operates in retarding or interrupting the rainfall," and shows that the pressure variations or pressure anomalies fail to account for rainfall failure or distribution. What that condition is he merely indicates as an important subject for

investigation, with an expression of the opinion that the confirmation requires watchfulness and judgment not to be expected from the "class of men who furnish the registers of our observatories." I understand him to take the snowfall in the North-Western Himalayas as the best, and in fact at that time the only available indication of different states of the upper atmosphere (of great elevations he observes).

At the time when the head of the Meteorological Department in India was evolving the above hypothesis or theory, that is in the early eighties, Mr. Eliot, then a subordinate in Bengal, was publishing (see Monthly Weather Reviews) rival forecasts based upon the principle which Mr. Blanford was declaring to be an insufficient guide. After he became in turn head of the Department, that principle became to the exclusion of all others the working guide in estimating the character of the rainfall, and in fact of all weather changes.

It is not easy to give chapter and verse for what I may select as the guiding principle, theory or hypothesis used by Mr. Eliot in weather forecasting, for owing to the immense amount of printed matter published since 1888 and the difficulty of finding what I may call incriminating statements, the search reminds one of a recent process which has been attracting much attention lately—the extraction of radium from pitchblende.

Perhaps the most explicit statement issued previous to the letter published in the *Pioneer* in 1899, is to be found in an extract from the papers of the Chicago Meteorological Congress, August 1893. The following extracts give, as Mr. Eliot then states, some of the conditions determining the character of the coming monsoon :—

(1) "Unusually heavy and prolonged snowfall in the Himalayan Mountain area has been shown by Mr. Blanford to exercise a very powerful influence."

(2) "The abnormal pressure conditions established during the hot weather, more especially if they are marked, exercise a great influence in modifying the set of the monsoon currents."

"A consideration of the snowfall data of the cold weather, of the meteorological conditions prevailing during the hot weather, and more especially the character and persistency of the pressure variations, usually enables a rough estimate of the general strength of the monsoon currents and the distribution of the rainfall to be made. ..... This is what is now attempted to be done in the forecasts issued annually in June by the Department and which have had a fair measure of success. For example, a full warning

was given in June 1891, of the drought in Rajputana during the monsoon rains of that year."

The paper closes with the following paragraph :—

"It is hardly necessary to point out that the methods employed and sketched above are practically identical with those employed in giving warning of the approach of storms, and I may again point out that these long period forecasts in India are rendered possible by the peculiar features of the South-West Monsoon air motion over India, and by the remarkable persistency of many of the abnormal conditions of the meteorology of that current."

The meaning of the statement regarding the full warning in June 1891 of the drought in Rajputana is shown by the following extract from a paper by Mr. Eliot on oscillatory changes of pressure published in 1895. Met. Mem. Vol. VI, page 92 :—

"The abnormal pressure conditions which enabled the Department to foretell accurately the last serious drought in India, *viz.*, that of 1891, in Rajputana, were small in amount, depending on pressure variations and anomalies not exceeding ·05" ———————."

The above extracts make it, in my opinion, sufficiently evident that the theory or hypothesis on which weather forecasting in India for long or short periods was conducted from 1888 to 1895, was the pressure anomalies or variations as disclosed by the barometric observations in the plains of India. A study of monsoon forecasts and other publications will, I believe, complete the proof (notwithstanding the statement in the Chicago paper) that Mr. Blanford's theory had ceased to be a living theory, but any such troublesome investigation is rendered quite unnecessary because the last annual summary to which Sir J. Eliot contributed, that of 1902, contains at his hands the complete *quietus* of that hypothesis. In page 708 of that summary the following occurs :—

"In the year 1902, the deficiency in the total rainfall due to the Arabian Sea was due solely to the weakness of the whole circulation of the South-East trades and South-West monsoon during more than half of its normal period. In some years of similar periods, as in 1885, the delay and weakness of the monsoon was associated with heavy prolonged and continuous snowfall during the cold and hot weather periods in the Western Himalayas. This was not the case in 1902, as the snowfall of the cold weather or winter of 1902 was one of the lightest on record. It is hence probable that actions and conditions in the Indian Ocean are primary, and conditions in India such as snowfall in the Himalayas subsidiary, and are of small importance relatively to

the former except when the conditions in the Indian Ocean and Seas are approximately normal."

It is unnecessary to follow the progress of weather forecasting through the years between 1895, and 1903, when the above opinion was written, or to consider the influence of American meteorologists in directing the development of Sir J. Eliot's opinions; or to show that the abnormal years, such as 1899, convinced even him that Mr. Blanford was right in the opinion that pressure anomalies form an unreliable guide in forecasting the weather in Northern India. All that is necessary is to show that in 1903, so far as hypothesis or theory went, the slate had practically been wiped clean, the snowfall theory had failed, the pressure anomalies had failed, the comparison with previous years had failed; and all that remained was to transfer the seat of cause and effect to the Indian Ocean or Seas, an area over which an active imagination may roam with but little restraint.

The following extracts from the report referred to, the Annual Summary for 1902, appear to support the opinion which I have given, that Sir J. Eliot believes the character of the monsoon to be determined in the Southern Seas:—

Page 688.

"The conditions in India itself hence fail to give any clue to the delay in the advent of the monsoon currents in June and July, and more especially of the Bombay or Arabian Sea current."

Page 705.

"The discussion of the Meteorology of India in the preceding pages has shown clearly:—

(1) That the conditions in India in the latter part of May and the commencement of June were such as are usually associated with an early and strong monsoon, more especially as judged by the data of the period 1875–1892, antecedent to the period of anomalous and remarkable conditions obtaining from 1892 to 1902.

(2) That there was no large or rapid change of meteorological conditions in India prior to the remarkable change in the character of the Arabian Sea Monsoon in the third week of August. The conditions then prevailing were such as invariably accompany a prolonged break in the rains, and are rather effects and not causes of the breaks. It hence follows that the causes, actions or conditions determining the weakness of the Arabian Sea current in the first half of the period, and its strength during the second half, are not to be sought for in India or the Indian monsoon land area, but most probably in

> the remaining portion of the area of the complete monsoon air circulation, *viz.*, the South-East trades region of the Indian Ocean."

Later in the same page: —

> "The preceding data show that the abnormal monsoon of 1902, accompanied abnormal conditions in the Indian Ocean unfavourable to a strong monsoon, although in India the conditions are favourable. This fact is almost sufficient to establish that the abnormal features of the monsoon of 1902 were due primarily, if not entirely, to abnormal features in the Indian Ocean."

Page 707.

> "It is not necessary to give further data, as the previous have been sufficient to establish fully that the variations in the strength of the Arabian Sea current in India were primarily and directly related to variations in the strength of the whole air movement over the Indian Ocean and Seas, and more especially to the movement in the Indian Ocean."

I have attempted to show by the above brief extracts what the controlling principle in weather forecasting has been from time to time, and these may, I think, be still more briefly summarised as follows:—

Mr. Blanford at first relied on pressure anomalies or variations, but afterwards found that method to be untrustworthy. His own observation showed that there was some other condition on which rainfall in Northern India depended, connected as he thought with the upper strata of the atmosphere and requiring careful investigation in the future. Taking the snowfall in the Himalayas as a tangible representation of that condition, he claimed to have repeatedly and successfully shown beforehand the character of the coming monsoon.

Sir J. Eliot was guided entirely by the pressure anomalies in India, as is shown by the claim to have foretold the nature of the famine in Rajputana in 1891. He was subsequently induced by the criticism of American meteorologists to extend the sphere of observation over a wider area, and when the pressure anomalies in India failed conspicuously in the later nineties, as Mr. Blanford had found them to fail nearly twenty years before, the discussion of the character of the coming monsoon resolved itself into a consideration of conditions over the Southern Sea area, and a comparison of what had happened in India in years said to be similar.

Still later the sunspot cycle has been put forward under an impetus from Sir Norman Lockyer.

During all these years nothing has been done towards investigating that other condition on which, according to Mr. Blanford, the rainfall in Northern India appeared to depend, connected with the upper strata of the atmosphere.

It has appeared to me that since 1897 the evidence has been becoming conclusive, not to say overwhelming, that without more information, such as Mr. Blanford required regarding the upper strata of the atmosphere, it is impossible to say even a few hours ahead what the character of the weather will be in Northern India. With the object of showing how important the changes are that appear to originate in the north, I have been collecting and publishing in the Journal of the Society all information available regarding what I have called Summer Himalayan storms and their influence on weather in Northern India.

These storms were unusually well-marked in 1902, the year which Sir J. Eliot states was sufficient in itself to show that the character of the monsoon in Northern India was determined by conditions in the Southern Indian Seas. In the two cases which I have discussed in some detail in the paper on two remarkable rainbursts in Bengal,—one on June 30th, 1902, the other on August 12th,—I showed that there was no evidence of any kind that the general change then in operation came from the south, whereas there was very strong evidence of a disturbance crossing the Himalayan range from the north.

Similar well-marked occurrences are on record for 1903, and the unusual weather in the United Provinces in the early part of October, can, I believe, be traced to the disturbance which entered Northern India from Central Asia in the closing days of September. As that weather called forth the criticism of the *Pioneer*, which I have quoted above, it may now be seen more clearly why I have quoted their remarks. In the first place the press extracts show that weather was settled over the southern seas, because it was anticipated on all hands that the monsoon was on the wane. In the second place the remarks of the *Pioneer* afford strong corroborative evidence that on that particular occasion something very unusual and unexpected had happened in Northern India. Also I may point out, as further justification for introducing these extracts, that similar occurrences in 1902 were passed over by Sir J. Eliot without comment, showing that an examination of registers only is not sufficient to account for passing events or, to quote Mr. Blanford again, there is certain information which we cannot expect from the men who furnish our registers.

Even Mr. Murray supports my contention that weather in 1902 was not entirely controlled from the south. In the Weather Review for

June 1902, among conclusions suggested by a discussion of the atmospheric conditions in Europe, Asia, Africa, Australia and the adjoining seas, the following occur :—

"That conditions in India may be sometimes largely conditioned by actions taking place in the Central Asian areas, and that occasionally these actions extend over the greater part of Europe and Asia."

"That these actions are largely modified by the barrier of the Himalayas, and seem to spread more readily southward through the gaps in the range."

I think the above remarks have made it clear how the subordinates of the Meteorological Department, entrusted with the duty of issuing forecasts in the first half of October, 1903, had no alternative but to estimate coming weather changes on the supposition that they originated in the southern sea area and approached Northern India from the south, and that an attempt by them to introduce any consideration of other conditions such as were thought to be necessary by Messrs. Blanford and Murray, would have been without sanction so long as Sir J. Eliot controlled meteorological work in India. Before proceeding to consider the striking changes which passed over Bengal from the north previous to the unexpected burst of rainfall in Northern India in October, I will give an illustration which appears to me to show in a simple way the great need there is for investigating the condition which Mr. Blanford, by observation and reasoning, found to be indispensable to an accurate estimate of coming weather.

The atmosphere is, on a large scale, nothing more than a condensing engine, the lower part constituting the boiler, the upper part the condenser. In settled weather there appears to be little or no passage of air from the lower to the upper sections of the atmosphere, and in an area of settled weather the air currents move on steadily and independently, and frequently, if not always, in opposite directions. Through some action which is never absent from some part of the atmosphere these currents interfere, cyclonic motion begins, ascensional motion follows, and the moisture laden air passes from the boiler to the condenser. Rainfall will then begin *provided that conditions in the upper strata of the atmosphere are favourable to condensation.* It is as regards this requirement that marked cleavage of opinion exists between Mr. Blanford and Sir J. Eliot. The former early saw that in any discussion of rainfall the condition of the condenser or upper strata of the atmosphere cannot be overlooked, and he has put on record his opinion that information on that head cannot be expected from the observers who furnish our registers of observations. The latter has relied entirely on these registers. When they failed he has said that the conditions were not determined

over India, and that the causes must be looked for in the southern seas. In other, words we have the case of an engineer who knows that the boiler of his engine is in perfect working order and fails to account for a break-down because he has never even looked at the condensing arrangements.

Towards the end of September, my attention was attracted to a change of weather which commenced in Assam and North Bengal. The first sign of the change was a fall of pressure, but that fall was of no value as an indication of important events pending, because we have similar and much larger changes occurring in the midst of the finest and most settled weather. The fall began on the 23rd September and continued on the 24th and was, in North Bengal, ·05 inch on an average, as may be seen from a table given below. Table IX below will show that rain began to increase in Assam on the 23rd, in North Bengal on the 24th, and in Lower Bengal on the 25th. Tables III and VII show that temperature began to fall in Assam on the 23rd, in North Bengal on the 24th, in Southwest Bengal on the 25th, and in Orissa on the 26th. Southerly winds strengthened in Lower Bengal, and in these early days there were all the signs of the occurrence of a Himalayan storm of the kind that I have, on previous occasions, written about. From Thursday, September 24th, I not only scrutinised carefully the daily weather report, but I almost continuously watched the appearance of the change so far as it came within my range of vision. I give below brief notes made at the time. Before doing so I may state that I was watching carefully for the passage northwards from the Bay into Bengal of an area of disturbed weather. I saw no indication of any such occurrence, and all I saw clearly indicated a sequence of change commencing in the north and progressing in a general southerly direction.

My notes were as follows :—

Thursday, September 24th.

Moderate fall of pressure general, wind S.W. at Darjeeling, temperature falling rapidly in North Bengal and Assam, rainfall general in the north and heavy in places (Daily Weather Report). I began watching the upper cloud movements. Characteristic cirrus visible, appeared to be moving from a southerly or south-easterly direction. Towards evening the cirrus thickened into what I should call stratus, and after dark distant and almost continuous lightning was visible in several directions, chiefly in the north but also in the north-west. There was no sign of disturbance towards the south.

Friday 25th.

Sky clear in the early part of the day with some low cumulus and cirrus much the same as the day before. Strongish southerly winds

continued below, but as far as I could make out, the direction of movement of the cirrus appeared to be from the north. In the afternoon I watched, for an hour between 3 and 4 P.M., a dark cloud creeping up from the north-west: it appeared to be at a great height, probably the same as the cirrus. Below that cloud the air was evidently in commotion, because there was at times a great deal of fracto-cumulus, and in places high cumuli unbroken. About 5-30 low cloud covered the sky and a thunderstorm broke over Calcutta from the north or north-west. Very heavy rainfall for a short time.

Saturday 26*th.*

Weather again fine during the day.

In the evening two thunderstorms developed near Calcutta; one passed eastward with a slight southerly element in its movement. The second was then visible in the west and moved slowly eastward, but by the time it reached Calcutta, about 9 P.M., the cloud was much diffused Ordinary rainfall began about 9 P.M., and continued for several hours.

Sunday 27*th.*

A depression has begun to form over Lower Bengal and the north of the Bay, but it is diffused, and changes being of a local character, it is difficult to account for what is going on. A thunderstorm was over Calcutta about noon.

Monday 28*th.*

The depression is somewhat better defined and is moving slowly westward. The most noticeable occurrences were as follows: In the early morning between 7 and 8 A.M., thick stratus overhead and a cumulus underneath towards the east. This cumulus moved slowly westward and was over this place about 9 A.M., with moderately heavy rainfall. In the forenoon a black cloud came up over Calcutta from the South-west, and heavy rain fell all the afternoon. The cloud was high when I noticed it and when the weather cleared up the clearing began from the north-east.

Tuesday 29*th.*

The depression was more to the west. Centre at 8 A.M., about equally distant from Saugor Island, Balasore and Midnapore.

Wednesday 30*th.*

The westerly movement has continued.

The above notes made at the time show what the main features of the weather were in Bengal at the end of September. These may be summarised as follows:—

(1) While weather was still fine and almost cloudless in Lower

Bengal and over the Bay a change began in the north of the Province and in Assam.

(2) This change shown by the occurrence of thunderstorms advanced southward over the Province.

(3) It had not reached Calcutta on Thursday, but knowing, as I believe I did, what was happening, the distant continuous lightning visible towards the north was to me a most impressive sight.

(4) The change passed over Calcutta on the 25th, and thereafter a depression almost immediately began to form over Lower Bengal and the north of the Bay.

Puja holiday people from Calcutta will remember that they left this place in fine weather, and that the Darjeeling and Himalayan Railway was most unexpectedly breached, further evidence that the disturbing influence was not from the south.

I have already referred to the fall of temperature which passed over Bengal on the 24th and 25th. Expecting some such change at Calcutta I borrowed, from the Presidency College, a thermograph and exposed it about noon on Friday the 25th. The thermograph trace here given extends for a week from the 25th. The weather in Calcutta at that time was fine and almost cloudless. In the place of exposure of the instrument, temperature, during the afternoon, rose to nearly 94°. The trace shows the sudden fall with the thunderstorm which occurred about 5 P.M. The temperature on Saturday was even higher during the day, and again there was the fall due to a thunderstorm about 5 P.M. Sunday, Monday and Tuesday show a steady fall of day temperatures as the depression formed and cloud increased. Wednesday and Thursday, the recovery after the depression moved westward. It is not my intention to give this temperature tracing as indicating the correct shade temperature for Calcutta. The thermograph was in a verandah with a free exposure to all directions except the north, and the high temperature at times indicated, as on Saturday the 26th, was due to the sun's rays falling on the instrument towards evening. I took no precaution to prevent high temperatures because my object was to show low temperatures.

The depression, which began over Lower Bengal on Sunday the 27th, moved westward into Central India, and then recurving towards the United Provinces gave the commencement of the "heavy and prolonged burst of rainfall" referred to in the *Pioneer*. It is unnecessary to follow the storm in its course; a reference to the Indian Daily Weather Report of those days will show the main features of the disturbance.

I have pointed out in previous papers that a striking feature of these Himalayan storms and their after-effects, has been the subsequent formation at brief intervals of depressions over the north of the Bay. It has been seen that on this occasion a depression formed over Lower Bengal on the 27th to 29th September and then moved westward. A second depression appeared over the north of the Bay a few days later about the 3rd October. This storm also moved westward, but in a direction more northerly than its predecessor, and after recurving in the southern parts of the United Provinces filled up over those Provinces about the 11th. The exceptional character of the weather in the United Provinces during the period October 1st to 10th was due to these two depressions, but the main cause of the rainfall was the recurving, or the causes thereof.

We have had the "remarkable series" of three cyclonic storms which saved the agricultural situation in Guzerat in 1902, following immediately after the Himalayan storm of August 12th. These cyclonic storms developed at intervals of seven days. Again this year we had the remarkable series of four cyclonic storms following the Himalayan storm of July 9th. These developed over the north of the Bay at intervals of five days. Their influence on the rainfall distribution in Northern India was very striking, but need not be referred to here.

Now we have a "remarkable series" of two cyclonic storms forming over the same area at an interval of seven days, at a time when such storms not unfrequently develop over the Bay, but on this occasion following an unexpected, I might say, an unprecedented course and causing what the *Pioneer* calls "one of the most heavy and prolonged bursts of rainfall that can have ever been recorded so late in the year."

Not only do these Himalayan storms appear to indicate an important cause in the formation of cyclonic storms in the Bay of Bengal, but they have, on all the occasions I have referred to, been followed by a marked alteration in the course or track of the cyclonic storms over Central and Northern India. That is, the recurving on which the rainfall distribution so largely depends, was materially affected.

That recurving, as I have pointed out, is not dependent on the lower strata of the atmosphere, and my reason for thinking so is that there is no occasion on record when recurving has been indicated beforehand by the ground-level observations.

It is in this connection that Mr. Blanford's insight receives such striking confirmation. Take for comparison the year 1882, and its monsoon experience. The extracts I have given show that at that time Mr. Blanford was giving form to the theory that there is an important

connection between the condition of the upper strata of the atmosphere and the rainfall distribution, and was taking careful note of all available information. Mr. Eliot in Bengal was at the same time explaining all changes by the ground-level observations, in fact by pressure variations. The year 1882 was in many of its features similar to 1903. There was the same remarkable series of cyclonic storms in July causing serious misgiving to the authorities in Bengal; there was in both years a change of the same kind early in August, and subsequently sufficient rainfall; there was a similar cyclonic storm at the end of the season, though not quite so late in 1882 as the first week of October. That is, all the more striking features of the monsoon season of 1882 have been repeated in 1903 (after an interval which, it may be noted, is suspiciously like two sunspot cycles). It is hardly necessary to repeat that these past few years have shown that the system on which weather forecasting has lately been worked has failed: but what cannot be too frequently repeated is that these past two years have supplied valuable evidence as to the reason for the failure, and that that evidence is in its more important aspects similar to what was before students of Meteorology in India in the early eighties. The failure has been due to the exclusive reliance placed on ground-level observations. If the line of investigation suggested by Mr. Blanford twenty years ago had been followed up, we would probably now have been able to take full advantage of the information to be extracted from the varied conditions of the series of years between 1897 and the present year.

In 1882, Mr. Blanford was pointing out that other information than what is supplied in the registers of the observatories is necessary to solve the weather problem in India. In 1903, Sir J. Eliot after twenty years more study of registers and without any assistance from an investigation of the upper strata, records his opinion that the character of the weather in India is determined in the southern seas.

The inference appears to me to be obvious. If we are to make headway with the problem of weather forecasting the lines must be taken up where they were laid down 16 years ago by Mr. Blanford.

It may be asked what means have been available for following out the investigation of the upper strata outlined twenty years ago. The answer may be, that meteorologists in Europe and America have been steadily developing and improving such methods, and that a considerable amount of information has been collected regarding the upper strata over those regions. That being so, the next question is what success in weather forecasting has followed this extension of the field of observation—a question to which a negative answer must be given

for a very good reason. Neither the United States of America, nor at least the British Isles, afford favourable conditions for the early steps in settling the part played by the different currents or strata of the atmosphere. In the United States the "highs" and "lows" on which weather variation largely depends, cross the west coast from the Pacific and usually follow an easterly course towards the Atlantic. There is but little of that variation which is indispensable for successful analysis. In Britain the actions are more variable but their beginnings and their endings are both unknown. It was only at the last meeting of the British Association that Dr Shaw, Secretary to the Meteorological Committee of the Royal Society, told his audience how unreliable the depression is as guide to weather changes, and his difficulty appeared to me to be as regards the origin of the depression.

In India, and more especially in Lower Bengal and over the north of the Bay, circumstances are much more favourable. We have clearly defined currents, which undergo considerable variation from season to season, and even from year to year; we have depressions forming over the north of the Bay during the monsoon and pre-monsoon months, with a great variety of subsequent occurrences as regards recurvature and rainfall distribution; in fact all that variety which may fairly be expected, on analysis, to yield the orderly sequence of cause and effect. But until the upper currents are made the subject of systematic observation any satisfactory solution is unlikely.

To take a simile from well-sinking, they appear to be boring for water in the United States where there is no water, and probably also in Europe; while here, where water exists and is much needed, the boring has not been begun. As soon as observation, such as was outlined by Mr. Blanford, is begun in Lower Bengal and adjacent tracts, results of the utmost value to meteorology may be confidently expected.

In my previous papers on these Himalayan storms I gave brief tables—one set arranged to show the progress of the disturbance southward from the part of the Himalayas where it first affected the weather, and the other set to show the progress westward. I give similar tables for the Himalayan storm now under discussion, and I will call it the storm of date September 24th, because that was the date on which it appeared, although the heaviest rainfall in North Bengal appears under date 25th, having been measured at 8 A.M. of the 25th.

(*For table see next page*).

TABLE I.

Giving the pressure change daily from September 22nd to September 30th, 1903, arranged to show the southward progress of the disturbance.

	September 22 Tuesday.	September 23 Wednesday.	September 24 Thursday.	September 25 Friday.
Assam	+·044″	−·008″	−·041″	+·040″
North Bengal ...	+·048	−·013	−·049	+·032
East Bengal	+·067	−·006	−·031	+·018
South-West Bengal ...	+·064	−·023	−·040	+·021
Orissa	+·061	−·009	−·037	+·011
Circars	+·044	+·011	−·012	+·009
Akyab	+·083	+·032	−·045	−·001
Diamond Island ...	+·073	+·011	−·024	+·030

	September 26 Saturday.	September 27 Sunday.	September 28 Monday.	September 29 Tuesday.	September 30 Wednesday.
Assam	−·026″	−·069″	−·028″	+·050″	+·048″
North Bengal ...	−·009	−·076	−·024	+·033	+·051
East Bengal ...	−·031	−·068	−·033	+·036	+·058
South-West Bengal ...	−·017	−·089	−·028	+·004	+·079
Orissa	−·009	−·088	−·021	−·024	+·027
Circars	+·009	−·092	−·027	−·022	−·009
Akyab	−·002	−·095	+·021	−·010	+·027
Diamond Island ...	−·007	−·035	−·040	−·014	−·003

TABLE II.

Giving the pressure variation from the normal from September 22nd to September 30th, 1903, arranged to show the progress of the disturbance southward.

	September 22.	September 23.	September 24.	September 25.
Assam	+·073″	+·062″	+·018″	+·042″
North Bengal ...	+·095	+·071	+·013	+·033
East Bengal	+·087	+·075	+·041	+·049
South-West Bengal ...	+·108	+·077	+·029	+·038
Orissa	+·111	+·094	+·049	+·050
Circars	+·077	+·083	+·065	+·066
Akyab	+·077	+·105	+·056	+·051
Diamond Island ...	+·054	+·062	+·036	+·063

	September 26.	September 27.	September 28.	September 29.	September 30.
Assam	+·005″	−·071″	−·100″	−·056″	−·015″
North Bengal ...	+·019	−·064	−·095	−·068	−·025
East Bengal ...	+·011	−·064	−·101	−·074	−·020
South-West Bengal ...	+·012	−·084	−·121	−·123	−·050
Orissa	+·032	−· 65	−·093	−·126	−·105
Circars	+·067	−·034	−·070	−·100	−·115
Akyab	+·044	−·057	−·041	−·056	−·034
Diamond Island ...	+·053	+·014	−·031	−·050	−·057

These tables give the daily pressure change and variation from the normal between September 22nd and 30th. As on previous occasions, these figures are averages for the observatories in each division, and my reason for giving averages instead of the reports supplied by each observatory is, as before, because of the peculiar character of the change then in progress. Thunderstorms were numerous in the front

line of the advancing disturbance, and anyone who has watched meteorological reports in such circumstances will be aware that there are irregularities due to local storms. I have given the averages to eliminate these irregularities as far as possible, and to show the advance of the general disturbance.

As on previous occasions, pressure changes are not of much assistance in showing the importance of the general change then in progress. There was a slow fall of pressure on the 23rd in Assam, Bengal and Orissa. It continued somewhat more rapidly on the 24th and extended to the Circars, Akyab and Diamond Island, which had not been affected on the 23rd. The recovery is general on the 25th, and the brisk fall on the 27th shows the development of the cyclonic storm over Lower Bengal and the north of the Bay.

In Table II the variations from the normal are given. It will be seen that pressure was in excess, considerable excess as it is usually measured in these parts, on the 22nd and 23rd; and that deficient pressure was not noticeably present until the 28th and 29th, when the shallow depression had formed over Lower Bengal and the north of the Bay.

TABLE III.

Giving the temperature change daily from September 22nd to September 30th, 1903, arranged to show the southward progress of the disturbance.

	September 22.	September 23.	September 24.	September 25.
Assam	+0·8°	−1·0°	−1·9°	−2·0°
North Bengal	+3·0	+1·2	−2·8	−2·0
East Bengal	+0·3	−0·6	−0·7	−2·1
South-West Bengal ...	−0·8	+0·6	+0·8	−1·6
Orissa	+0·4	−0·2	+0·3	+0·6
Circars	−0·9	−0·1	−0·7	+1·4
Akyab	+1·5	−2·0	−1·0	+1·5
Diamond Island ...	+0·8	+0·2	+0·5	+0·5

	September 26.	September 27.	September 28.	September 29.	September 30.
Assam	+0·5°	−0·1°	+2·8°	+0·6°	+0·2°
North Bengal ...	−1·4	+2·9	+0·3	+0·9	−0·3
East Bengal ...	−0·2	+0·9	−1·0	0	+0·6
South-West Bengal ...	−1·3	+0·8	−1·3	−1·8	−0·1
Orissa	−1·3	−0·2	−0·6	−2·3	−1·9
Circars	+1·1	+0·2	−0·8	−0·2	−3·1
Akyab	−0·5	−1·0	−3·3	+0·3	+3·5
Diamond Island ...	−1·2	−1·8	0	+2·0	0

TABLE IV.

Giving the temperature variation from the normal from September 22nd to September 30th, 1903, arranged to show the southward progress of the disturbance.

	September 22.	September 23.	September 24.	September 25.
Assam	+1·7°	+1·5°	−1·5°	−2·9°
North Bengal ...	+0·8	+2·4	+0·5	−1·6
East Bengal	+1·7	+1·2	+0·6	−1·4
South-West Bengal ...	+0·8	+1·5	+2·7	+1·2
Orissa	+1·5	+1·3	+1·6	+2·4
Circars	−0·4	−0·5	−1·3	+0·1
Akyab	+1·6	−0·5	−1·5	0
Diamond Island ...	+2·5	+2·6	+3·1	+3·5

	September 26.	September 27.	September 28.	September 29.	September 30.
Assam	−2·8°	−2·8°	+0·2°	+0·5°	+1·2°
North Bengal ...	−2·8	−0·3	−0·5	+0·3	−0·2
East Bengal ...	−1·7	−0·9	−1·9	−2·0	−1·5
South-West Bengal ...	−0·2	+0·6	−0·8	−2·6	−2·8
Orissa	+1·4	+1·3	0	−2·2	−4·3
Circars	+1·3	+1·4	+0·6	+0·3	−2·8
Akyab	−0·5	−1·5	−4·9	−4·7	−1·2
Diamond Island ...	+2·2	+0·3	+0·2	+2.1	+2·0

These changes and variations of temperature are not large, but they show, at least as regards Bengal and Assam, that a change began in the north-east on the 23rd, was well-marked in North Bengal on the 24th, in South-West Bengal on the 25th, and in Orissa on the 26th. They also show that the period of greatest departure from the normal was between the 24th and 27th September in Assam, the 25th and 26th in North Bengal, and on the 26th in East Bengal. These indicate the progress of the change which passed over Bengal. The larger defect of the 30th in Lower Bengal, Orissa and the Circars is due to the cloudy weather which became general with the formation of the depression over Lower Bengal and the north of the Bay.

TABLE V.

Giving the pressure change daily from 22nd to 30th September 1903, arranged to show the Westward movement of the disturbance.

	September 22.	September 23.	September 24.	September 25.
Assam	+·044″	−·008″	−·041″	+·040″
North Bengal ...	+·048	−·013	−·049	+·032
Bihar	+·060	−·036	−·047	+·016
United Provinces ...	+·118	−·035	−·054	−·027
Punjab	+·097	−·009	−·052	−·034
Srinagar, &c.	+·055	−·015	−·022	+·008

	September 26.	September 27.	September 28.	September 29.	September 30.
Assam	−·026″	−·069″	−·028″	+·050″	+·048″
North Bengal ...	−·009	−·076	−·024	+·033	+·051
Bihar	+·004	−·069	−·012	+·014	+·050
United Provinces ...	+·015	−·059	+·021	+·001	+·060
Punjab	+·005	−·050	+·038	+·015	+·049
Srinagar, &c. ...	+·009	−·052	+·016	+·020	−·002

TABLE VI.

Giving the pressure variation from the normal from 22nd to 30th September 1903, arranged to show the westward movement of the disturbance.

	September 22.	September 23.	September 24.	September 25.
Assam	+·073″	+·062″	+·018″	+·042″
North Bengal	+·095	+·071	+·013	+·033
Bihar	+·108	+·065	+·010	+·016
United Provinces ...	+·099	+·061	+·002	−·029
Punjab	+·047	+·030	−·026	−·067
Srinagar	+·034	0	−·030	−·044
Leh	+·082	+·069	+·048	+·064

	September 26.	September 27.	September 28.	September 29.	September 30.
Assam	+·005″	−·071″	−·100″	−·056″	−·015
North Bengal ...	+·019	−·064	−·095	−·068	−·025
Bihar	+·011	−·064	−·086	−·078	−·035
United Provinces ...	−·023	−·089	−·076	−·081	−·031
Punjab	−·070	−·126	−·096	−·091	−·048
Srinagar	−·050	−·127	−·109	−·046	−·064
Leh	+·081	+·005	+·004	+·018	−·009

These tables show a general fall of pressure along the Himalayan range on the 23rd and 24th. The only indication of any westward movement is the recovery of pressure on the 25th in Assam, North Bengal and Bihar, and on the 26th in the United Provinces and the Punjab.

One matter which may deserve special comment is the rather large defect on the 27th in the Punjab and at Srinagar. It has been pointed out in a previous paper that there appears to be the same tendency to the formation of a cyclonic arrangement of winds in the Punjab after one of these disturbances as in Lower Bengal and the north of the Bay. The deficiency noticed above may be the indication of that tendency in the present case. If so, it was of very brief duration and almost immediately disappeared.

TABLE VII.

Giving the temperature change daily from 22nd to 30th September 1903, arranged to show the westward movement of the disturbance.

	September 22.	September 23.	September 24.	September 25.
Assam	+0·8°	−1·0°	−1,9°	−2·0°
North Bengal	+3·0	+1·2	−2·8	−2·0
Bihar	+2·2	+1·5	−0 3	−2.1
United Provinces ...	−2·0	−0·1	+1·2	+0·5
Punjab	+0·5	−0·8	+0·6	+0·5
Srinagar, etc. ...	−0·2	+0·2	−1·0	+1·2

	September 26.	September 27.	September 28.	September 29.	September 30.
As am	+0·5°	−0·1°	+2·8°	+0·6°	+0·2°
North Bengal ...	−1·4	+2·9	+0·3	+0·9	−0·3
Bihar	−2·1	+1·6	+0·4	+0·7	−0·7
United Provinces ...	+0·7	−1·0	−0·6	+1·0	+0·8
Punjab	+0·3	−0·6	−0·7	−0·3	+0·3
Srinagar, etc. ...	+0·6	+0·1	−0·2	+0·1	−0·1

TABLE VIII.

Giving the temperature variation from the normal from 22nd to 30th September 1903, arranged to show the westward movement of the disturbance.

	September 22.	September 23.	September 24.	September 25.
Assam	+1·7°	+1·5°	−1·5°	−2·9°
North Bengal ...	+0·8	+2·4	+0·5	−1·6
Bihar	+0·6	+2·5	+2·5	+0·9
United Provinces ...	−0·4	−0·4	+0·9	+1·6
Punjab	+3·4	+2·9	+3·7	+4·4
Srinagar	+7·1	+6·1	+7.1	+7·4
Leh	+1·7	+3·1	+2·3	+3·0

	September 26.	September 27.	September 28.	September 29.	September 30.
Assam	−2·8°	−2·8°	+0·2°	+0·5°	+1·2°
North Bengal ...	−2·8	−0·3	−0·5	+0·3	−0·2
Bihar	−1·4	+0·5	+0·7	+1·3	+0·5
United Provinces ...	+2·4	+1·5	+1·0	+2·1	+3·1
Punjab	+4·9	+4·5	+4·1	+4·1	+4·3
Srinagar ...	+9·1	+9·6	+11·0	+9·9	+9·5
Leh	+4·4	+5·8	+4·5	+5·4	+5·9

Table VII shows that temperature began to fall in Assam on the 23rd, and that the change appeared in Bihar on the 24th. A rapid fall was general in Assam, North Bengal and Bihar on the 25th, but it did not extend to the United Provinces. There was practically no fall of temperature in the United Provinces until later, when the depressions moved northwestward from the north of the Bay in the first week of October.

TABLE IX.

Rainfall (22nd to 30th September, 1903.)

	No. of Stations.	September 22.	September 23.	September 24.	September 25.
Assam	6	0·56	3·94	5·95	4·83
North Bengal ...	7	1·35	1·52	4·77	14·07
East Bengal ...	7	3·98	0·78	2·05	5·02
South-West Bengal ...	9	5·64	0·33	*Nil*	3·73
Bihar	13	5·03	0·03	2·35	6·92
United Provinces ...	11	4·93	1·50	2·22	1·12
Punjab	12	*Nil*	*Nil*	*Nil*	0·35
Simla Hills	5	0·91	0·67	0·07	0·53
Kashmir	6	*Nil*	*Nil*	*Nil*	*Nil*
Darjeeling	...	*Nil*	0·82	0·29	1·86
Cherrapunjee ...	...	*Nil*	0·25	0·75	1·36
Orissa	4	0·02	0·24	*Nil*	0·06
Circars	4	0·90	1·74	1·49	*Nil*

	September 26.	September 27.	September 28.	September 29.	September 30.
Assam	8·13	0.35	2·14	0·80	0·15
North Bengal ...	11·12	3·46	1·05	1·00	0·84
East Bengal ...	3·81	11·66	3·77	3·14	0·98
South-West Bengal ...	6·59	2·46	8·59	10·97	4·05
Bihar	6·08	3·37	1·57	0·19	0·55
United Provinces ...	5·29	0·85	0·62	*Nil*	0·28
Punjab	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
Simla Hills ...	0·04	*Nil*	0·69	*Nil*	0·19
Kashmir ...	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
Darjeeling ...	0·77	0·46	0·02	0·16	1·04
Cherrapunjee ...	0·87	0·07	*Nil*	0·56	0·30
Orissa	0·88	0·67	5·29	6·72	5·16
Circars ...	0·02	*Nil*	0·46	1·68	0·61